Instruction manual and data sheet PCA-100-05-10-1060-x

Photoconductive THz antenna for laser excitation wavelengths $\lambda \sim 800$ nm … 1130 nm

PCA – Photoconductive Antenna

PCA-100-05-10-1060-0 - unmounted antenna chip 4 mm x 4 mm with 4 bond contact pads
PCA-100-05-10-1060-h - mounted antenna on hyperhemispherical silicon substrate lens
PCA-100-05-10-1060-a - mounted antenna on aspheric focusing silicon substrate lens
PCA-100-05-10-1060-h-f - fiber coupled antenna on hyperhemispherical silicon substrate lens

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1. Spectral Performance

![Graph showing spectral performance with Emitter: JAM 635 bPCA-100-05-10-h-CTL, Detector: JAM 635 bPCA-100-05-10-h-CTL, 15 mW on both antennas, Emitter voltage 15 V.]

![Graph showing spectral amplitude with Emitter: JAM 635 bPCA-100-05-10-h-CTL, Detector: JAM 635 bPCA-100-05-10-h-CTL, 15 mW on both antennas, Emitter voltage 15 V.]

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2. **PCA applications**

The PCA can be used as terahertz (THz) emitter or detector in pulsed laser gated broadband THz measurement systems for time-domain spectroscopy in the frequency region from 0.1 to 2.0 THz. It also can be used as photomixing emitter or detector in tunable cw THz measurement systems up to 0.5 THz.

**Main PCA data**
- Laser excitation wavelength: 1060 nm
- Antenna gap: 5 µm
- Bow tie antenna length: 100 µm
- Antenna chip size: 4 mm x 4 mm

3. **Antenna Design**

![Antenna Design Diagram](image)

4. **Antenna parameters**

**Electrical parameters**
### Parameter

#### Dark resistance
- Minimum ratings: 15 M
- Standard: 18 M
- Maximum ratings: 25 M

#### Dark current @ 10 V
- Minimum ratings: 8 µA
- Standard: 13 µA
- Maximum ratings: 20 µA

#### Voltage
- Minimum ratings: 15 V
- Standard: 15 V
- Maximum ratings: 20 V

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**Dark current voltage characteristic at T = 300 K**

![Current-voltage characteristic PCA-100-05-10-1060](image)

**Optical excitation parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical absorption</td>
<td>84% @ 1060 nm</td>
<td></td>
</tr>
<tr>
<td>Optical mean power</td>
<td>20 mW</td>
<td>30 mW</td>
</tr>
<tr>
<td>Carrier recovery time</td>
<td>300 fs</td>
<td></td>
</tr>
</tbody>
</table>
Spectral absorbance
5. Mounted PCA on hyperhemispherical substrate lens: PCA-100-05-10-1060-h

<table>
<thead>
<tr>
<th>Photoconductive antenna</th>
<th>substrate</th>
<th>semi-insulating GaAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>chip area</td>
<td>4 mm x 4 mm</td>
<td></td>
</tr>
<tr>
<td>thickness t</td>
<td>630 µm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hyperhemispherical lens</th>
<th>material</th>
<th>undoped HRFZ-silicon,</th>
</tr>
</thead>
<tbody>
<tr>
<td>specific resistance $\rho$</td>
<td>&gt;10 kΩ cm</td>
<td></td>
</tr>
<tr>
<td>refractive index $n$</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>diameter</td>
<td>12 mm</td>
<td></td>
</tr>
<tr>
<td>height $h$</td>
<td>7.1 mm</td>
<td></td>
</tr>
<tr>
<td>distance $d$</td>
<td>7.7 mm</td>
<td></td>
</tr>
</tbody>
</table>

| Terahertz beam          | collection angle $\alpha$ | 57° |
|                        | divergence angle $\beta$ | 15° |
| virtual focus length $L$ | 26.4 mm |

The PCA chip is optically adjusted and glued on the hyperhemispherical silicon lens. The alignment of the PCA chip centre is done with respect to the optical axis of the silicon lens.

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The silicon lens is glued on the aluminium mount.

The two antenna contacts are wire bonded on a printed circuit board, which provides the connection to a 1m long coaxial cable with BNC or SMA connector.

A central hole in the aluminium mount allows the Terahertz radiation to escape from the hyperhemispherical silicon lens.

The antenna can be used as terahertz emitter or detector in pulsed laser gated broadband THz measurement systems for time-domain spectroscopy and as photomixing emitter or detector in tunable cw THz measurement systems in the frequency region from 0.1 to 2.0 THz (see schematics below).

**Schematic of a time-domain spectroscopy setup**
Fig. 1 Schematic of a time-domain spectroscopy setup
### 6. Mounted PCA on aspheric focusing substrate lens: PCA-100-05-10-1060-a

#### Photoconductive antenna
- **substrate**: semi-insulating GaAs
- **chip area**: 4 mm x 4 mm
- **thickness t**: 630 µm

#### Aspheric lens
- **material**: undoped HRFZ-silicon
- **specific resistance ρ**: >10 kΩcm
- **refractive index n**: 3.4
- **diameter**: 12 mm
- **height h**: 8 mm
- **distance d**: 8.6 mm
- **rough AR surface**

#### Terahertz beam
- **focal length f**: 53 mm
- **collection angle α**: 57.6°
- **convergence angle β**: 6.8°

#### Airy disc diameter
- **at 300 GHz**: 5 mm
- **at 1 THz**: 1.5 mm
- **at 3 THz**: 0.5 mm

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![Terahertz beam diagram](https://via.placeholder.com/150)

**Aluminium mount**
- 25.4 mm diameter, 6 mm thick

**Coaxial cable**
- type RG174 U, impedance 50Ω, capacitance 96pF/m, 1 m long

**Connector type**
- BNC or SMA

- The PCA chip is optically adjusted and glued on the aspheric silicon lens. The alignment of the PCA chip centre is done with respect to the optical axis of the silicon lens.

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- The silicon lens is glued on the aluminium mount.
- Two antenna contacts are wire bonded on a printed circuit board, which provides the connection to a 1m long coaxial cable with BNC or SMA connector.
- A central hole in the aluminium mount allows the Terahertz radiation to escape from the aspheric silicon lens as a focused beam with a focus 53 mm away and an Airy disc diameter dependent on the THz frequency.

PCA with aspheric silicon lens, coaxial cable RG 178 and BNC connector

Front view on mounted PCA (laser side)  Back view on mounted PCA (THz side)
7. Setup with Teflon lenses

We recommend the usage of PTFE lenses for the THz beam optics. This solution ensures good spectral performance of your spectrometer and is easier to handle as the usage of off-axis-parabolic mirrors. We offer mounted antennas with collimating teflon lenses (CTL-D25). These mounts can be upgraded with a second lens with a focal length of 30 mm (FTL-f30mm). You can then choose if you like to work with a collimated or focused THz beam.

Module CTL-D25

THz beam in the module

CTL-D25 combined with FTL-f30mm

THz beam in the combination of CTL-D25 and FTL-f30mm
8. Instructions for use of the PCA-100-05-10-1060-x

Emitter:
The pulsed laser beam (in case of time domain spectroscopy) or the mixed cw laser beam (in case of cw THz emitter) has to be focussed onto the antenna gap using an appropriate lens or objective with a beam diameter of about 5 μm to bridge the antenna gap with photo-excited carriers within the semiconductor. At the same time a voltage $U \approx 15$ V (maximum 20 V peak voltage) has to be supplied on the gap by connecting the BNC connector cable to a voltage source. The recommended optical mean laser power $P_{\text{opt}}$ is 20 mW (maximum 30 mW).

Receiver:
The pulsed laser beam (in case of time domain spectroscopy) or the mixed cw laser beam (in case of cw THz emitter) has to be focussed onto the antenna gap using an appropriate lens or objective with a beam diameter of about 5 μm to bridge the antenna gap with photo-excited carriers within the semiconductor. The phase of the laser beam with respect to the beam on the emitter site has to be adjusted by using an optical delay line in such a way, that the measured value of the THz field on the antenna meets a maximum of the optical beam. By changing the path difference between the emitter and receiver antenna the time-dependent shape of the THz field can be measured. The cable with the BNC connector must be connected with a sensitive electronic current amplifier.

PCA-100-05-10-1060-x-y-p with Integrated preamplifier:
If the antenna has an integrated preamplifier on the PCB, the four wire cable of the antenna (2 wires for bias supply, 2 wires for the amplified output signal) must be connected to the power supply using the Sub-D connector. The output signal is then available on the BNC connector on the power supply to measure it using an oscilloscope or a lock-in detector.

Attention: Please be sure, that the focusing lens or the lens mounting parts does not touch the antenna chip or the tiny gold contact wires between the antenna chip and the PCB. See figure "front view on mounted PCA (laser side)" above.

Lock-in detection
Because of the small detector signal a lock-in detection scheme is recommended. The following two possibilities for lock-in detection can be used:

- An optical chopper can be used in front of the emitter antenna to chop the optical beam with a frequency $\sim 1$ kHz. The result is a chopped emitted THz signal, which meets the detector antenna. The output of the detector antenna is than an alternating current, which can be amplified using an ac amplifier and rectified using a standard lock-in system. The disadvantage of this system is the loss of 50 % of the optical excitation power on the emitter antenna.
• A square wave voltage generator with an output voltage \( U \) of maximum +/- 20 V and a frequency of some kHz can be used as supply for the emitter antenna. The result is an emitted alternating THz signal, which meets the detector antenna. The output of the detector antenna is than an alternating current, which can be amplified using an ac amplifier and rectified using a standard lock-in system. This setup is shown in fig.1.

9. Order information

PCA-100-05-10-1060-x  
Photoconductive antenna

<table>
<thead>
<tr>
<th>length</th>
<th>( l ) = 100 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>gap</td>
<td>( g ) = 5 µm</td>
</tr>
<tr>
<td>width</td>
<td>( w ) = 10 µm</td>
</tr>
<tr>
<td>laser wavelength</td>
<td>( \lambda ) = 1060 nm (800 nm … 1130 nm)</td>
</tr>
</tbody>
</table>

\( x \) denotes the type of mounting as follows:

\( x = 0 \)  unmounted chip 4 mm x 4 mm with 4 bond contact pads

\( x = h \)  mounted on an Al disc with 25.4 mm \( \oslash \) and hyperhemispherical silicon substrate lens, 1m coaxial cable with BNC or SMA connector

\( x = a \)  mounted on an Al disc with 25.4 mm \( \oslash \) and aspheric focusing silicon substrate lens, 1m coaxial cable with BNC or SMA connector

\( x = h-f \)  fiber coupled antenna with hyperhemispherical silicon substrate lens